LCA Case Studies

Aquatic Ecotoxicity for Common Crop Protection Aids

ECA-Equivalency Factors for 65 Frequently Used Herbicides and Pesticides

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Abstract

Crop protection aids, used in the agriculture phase, contribute a great deal to the environmental impact of food products. An adequate inclusion of those substances in life cycle assessment is usually hampered by the lack of relevant equivalency factors. In this paper rough equivalency factors are given for 65 frequently used herbicides and pesticides. Those factors are calculated according to the methodology, originally developed by EPA, which was used by CML in 1992. It is acknowledged that equivalency factors, derived in this way, have a limited value. They only indicate potential impacts, ignoring the fate of such substances. However, as long as better data are lacking, these figures provide a useful approximation.

Keywords: Aquatic ecotoxicity (ECA), crop protection aids, ECA-equivalency factors; aquatic ecotoxicity (ECA), herbicides, ECA-equivalency factors; aquatic ecotoxicity (ECA), pesticides, ECA-equivalency factors; crop protection aids, aquatic ecotoxicity, ECA-equivalency factors; ECA-equivalency factors, crop protection aids; ECA-equivalency factors, herbicides; ECA-equivalency factors, pesticides; equivalency factors, ECA, crop protection aids; equivalency factors, ECA, herbicides; equivalency factors, ECA, pesticides; herbicides, aquatic ecotoxicity, ECA-equivalency factors; pesticides, aquatic ecotoxicity, ECA-equivalency factors

1 Introduction

All LCA-studies for food products carried out so far show that a substantial part of the environmental impact occurs in the agriculture phase. Apart from energy consumption for the production of fertilizer and for agricultural activities on the land, aquatic ecotoxicity due to crop protection agents may have a substantial environmental impact. At this moment only a few references provide equivalency factors for pesticides and herbicides. A frequently used source is the LCA manual, issued by CML (Heijungs et al., 1992). CML have extrapolated EPA data (EPA, 1984), which is a very practical approach, although it is not impeccable. Different species may have significantly different sensitivities towards individual chemical compounds. Therefore aquatic toxicity factors are measured for various species, and subsequently combined to one equivalence factor. In case only one or two toxicity factors are available, an extrapolation factor is used, which tends to favour those substances for which EC_{50}-values for more categories of organisms have been established. An even better approach would be to include the impact of chemical compounds over time, using so-called fate modelling. That more sophisticated approach has recently been described by CML and RIVM in a report about toxicity aspects in LCA (Guinée, 1996). In that document the fate of substances in the environment has been included. Biodegradation of substances in the environment and transport of substances between compartments (air, water and soil) are processed in a computer model called USES 1.0.

Both CML publications mentioned before only cover a minor part of the pesticides and herbicides currently used in agriculture. During our work on LCA for food products since 1990, we have developed an up-to-date list with currently used crop protection agents. In this communication we report the aquatic ecotoxicity potential for those substances, as calculated using the EPA extrapolation factors. Obviously more realistic figures would be obtained using fate modelling techniques, but for most substances the information necessary to make such calculations is still lacking. Until the moment that such data will be available, it seems to be most practicable to have an extensive set of equivalence factors for commonly used protection aids, which is based on a common set of toxicity measurements.

2 Method

The list of pesticides in this paper includes substances which have been found in agricultural recommendations, mainly for oil crops. Main sources of information are French

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agricultural recommendations for sunflower and rape seed production published by Cetiom (CETIOM, 1994) and information from the United States Department of Agriculture (USDA, 1993).

Equivalency factors for aquatic ecotoxicity for those substances were calculated according to the methodology developed by EPA (EPA, 1984), which was slightly modified by Meent (MEENT, 1990). As was discussed by CML this approach provides a first approximation for actual ecotoxicity, as it is based on various toxicity data. Such data are determined for various groups, e.g. algae, molluscs, crustaceans and fish. The lowest of the LC_{50} or EC_{50} is used as MTC (Maximum Tolerable Concentration). This MTC has been used for calculating the dilution volume ECA (Ecotoxicity Aquatic). ECA is the volume of water (m^3) required to dilute one mg of pesticides to its maximum tolerable concentration. As safety margin EPA uses an extrapolation factor F. In case only acute toxicity data for one or two groups are available F equals 0.001. In case acute toxicity data for at least one representative of the three groups are known, then F equals 0.01.

The equivalency factor (ECA) is calculated as follows:

$$ECA = \frac{1}{MTC * F}$$

3 Result and Discussion

Toxicity data have been obtained from an extensive study by Linders from the Dutch Institute RIVM (LINDERS, 1994). In **Table 1** all relevant data are summarised, as well as the calculated equivalency factors. For those substances that were mentioned in the CML manual (CML, 1992), the ECA-factor derived there is also included in **Table 1** (*Appendix, p. 202*). The (sometimes considerable) differences between this study and CML should be attributed to different EC_{50}-values used, although the background of those differences has not been investigated.

From the list with 65 crop protection aids in this study only 5 substances are mentioned in the new CML/RIVM report (GUINÉE, 1996). The authors have addressed that issue by stating that the reader can perform his own calculations with USES 1.0. However, there is no public database containing the required substance data, and hence they admit that data availability will remain an important limitation. From a scientific point of view the new approach is a significant step forward in including the impact of toxic emissions in LCA. A lot of work still has to be done before an extended list of toxic compounds with corresponding factors will be available. In the mean time LCA practitioners need a tool to rank toxic compounds on their potential environmental impact. The data in this paper can be used for screening purposes, keeping in mind that the list only provides a rough check on toxicity, and knowledge about toxicity aspects of pesticides. Therefore this list should not be used for other purposes than rough estimations.

It also is important to realise that LCA cannot usually predict impacts. Risk assessment is required for that, including a prediction of the likely level of exposure or dose at specific locations. For this reason it must be re-emphasized that at best LCA provides an indication of the potential to cause an impact. A detailed risk assessment should be undertaken, before any conclusion can be reached about the actual environmental impact.

4 References

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Appendix

Table 1: ECA-Equivalence factors for some frequently used herbicides and pesticides

Active ingredient	Type (a)	EC50 algae ml/l (h)	LC50 crustaceans mg/l (b)	LC50 fish mg/l (b)	extrapolation factors 0.001	0.01	Max. tolerable conc. MTC	Calc. equiv. fac. aquatic ecotoxicity ECA (m3/mg) This study	CML, 1992
2,4-D	h		150	4	•		4.0E-03	2.5E-01	2.5E-01
alachlor	h	0.11	10	1.8		•	1.1E-03	9.1E-01	
aldicarb	n			0.1	•		1.0E-04	1.0E+01	3.1E+00
asulam	h		32	5000	•		3.2E-02	3.1E-02	
atrazine	h		5.7	6.3	•		5.7E-03	1.8E-01	5.0E+00
bentazone	h	280	64	510		•	6.4E-01	1.6E-03	
captan	f	1	1.8	0.05	•		5.0E-04	2.0E+00	1.9E+01
carbaryl	i		0.006	0.75	•		6.0E-06	1.7E+02	
carbetamide	h	3.3	4.1	14		•	3.3E-02	3.0E-02	
chlorfenvinphos	i	1.6	0.0002	0.039		•	2.0E-07	5.0E+03	
chloridazon	h		0.18	34	•		1.8E-03	5.6E-01	
chlorpropham	h	3.3	4.1	14		•	3.3E-02	3.0E-02	
chlorpyriphos	i		0.00011	0.003	•		1.1E-07	9.1E+03	
chlorthalonil	f		0.07	0.047	•		4.7E-05	2.1E+01	
cyanazine	h	0.02	42	5	•		2.0E-04	5.0E+00	
cycloxydim	h	32	130	100		•	3.2E-01	3.1E-03	
deltamethrin	i		0.0008	0.00058	•		5.8E-07	1.7E+03	1.0E+03
dimethoate	i	300	2.9	30		•	2.9E-02	3.4E-02	
ethofumesate	h	0.06	300	11		•	6.0E-04	1.7E+00	
ethoprophos	n	28	0.05	0.27		•	5.0E-04	2.0E+00	
etrimfos	i	2.9	0.0037	0.1		•	3.7E-05	2.7E+01	
fenamiphos	n	3.5	0.0016	0.01		•	1.6E-05	6.3E+01	
fenpropimorph	f	2.2	3.9	3.2		•	2.2E-02	4.5E-02	
fentin-acetate	f		0.011	0.01	•		1.0E-05	1.0E+02	2.0E+01
flusilazole	f	6.6	3.4	1.2		•	1.2E-02	8.3E-02	
fonofos	i	1.5	0.0023	0.028		•	2.3E-05	4.3E+01	
glyphosate	h	15	780	86		•	1.5E-01	6.7E-03	
heptonophos	i	35	0.002	9.3		•	2.0E-05	5.0E+01	
hymexazole	f	1.8	4.9	1.2		•	1.2E-02	8.3E-02	
iprodione	f	15	4.7	2.3		•	2.3E-02	4.3E-02	
lindane	i	1	0.0195	0.002		•	2.0E-05	5.0E+01	2.5E+00
linuron	h		0.75	3.2	•		7.5E-04	1.3E+00	2.0E+01
maneb	f	3.2	0.0024	0.3		•	2.4E-05	4.2E+01	1.1E+00
MCPA	h		1100	2000	•		1.1E+00	9.1E-04	1.7E+01
mecoprop	h	220	420	147		•	1.5E+00	6.8E-04	2.5E+01
mercaptodimethur	i			0.79	•		7.9E-04	1.3E+00	
metalaxyl	f	42	610	100		•	4.2E-01	2.4E-03	
metamitron	h	0.2	100	440		•	2.0E-03	5.0E-01	
metazachlor	h	1.6	22	4.4		•	1.6E-02	6.3E-02	
methamidophos	i	86	0.026	46		•	2.6E-04	3.8E+00	
methiocarb	i			0.79	•		7.9E-04	1.3E+00	
metolachlor	h	0.067	25	2		•	6.7E-04	1.5E+00	
mevinphos	i		0.00016	11	•		1.6E-07	6.3E+03	1.0E+03
monolinuron	h	0.001	32	74		•	1.0E-06	1.0E+03	
oxamyl	n	3	5.7		•		3.0E-03	3.3E-01	2.4E+00
oxydemeton-methyl	n	100	0.0033	1.9		•	3.3E-05	3.0E+01	5.3E+01
parathion (-ethyl)	i		0.0018	0.71	•		1.8E-06	5.6E+02	2.5E+02
pendimethalin	h	0.055	0.08	0.14		•	5.5E-04	1.8E+00	
permethrin	i	0.013	0.0002	0.00067		•	2.0E-06	5.0E+02	7.1E+02
phenmediphfam	h	1.4	6.5	2.7		•	1.4E-02	7.1E-02	
phosphamidon	i	260	0.022	3.2		•	2.2E-04	4.5E+00	
pirimicarb	i	140	0.019	32		•	1.9E-04	5.3E+00	
prometryn	h		19	2.9		•	2.9E-03	3.4E-01	
propamocarb	f	350	280	160		•	1.6E+00	6.2E-04	
propoxur	i	5.3			•		5.3E-03	1.9E-01	
propyzamide	h	5.5	5.6	72		•	5.5E-02	1.8E-02	
pyrifenox	f	0.095	3.6	6.6		•	9.5E-04	1.1E+00	
sethoxydim	h		120	30	•		3.0E-02	3.3E-02	
terbufos	i	1.4	0.00031	0.0008		•	3.1E-06	3.2E+02	
thiram	f	1	0.00006	0.27		•	6.0E-07	1.7E+03	6.3E+01
triadimenol	f	3.7	2.5	17		•	2.5E-02	4.0E-02	
triazophos	i			0.041	•		4.1E-05	2.4E+01	2.0E+02
triclorfon	i			1.6	•		1.6E-03	6.3E-01	1.0E+03
trifluralin	h		0.27	0.42	•		2.7E-04	3.7E+00	5.0E+00
vinclozolin	f	32	4	27		•	4.0E-02	2.5E-02	

(a) herbicides (h), fungicides (f), insecticides (i) and nematocides (n)
(b) data from Linders, 1994